SUPPORTING TARGET 4 OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION BY INTEGRATING ECOLOGICAL RESTORATION INTO THE MISSOURI BOTANICAL GARDEN'S CONSERVATION PROGRAM IN MADAGASCAR[1]

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Abstract

The Missouri Botanical Garden (MBG) is supporting community-based conservation at 11 priority areas for plant conservation in Madagascar. Our strategy for conserving these sites integrates a range of activities that include research and monitoring, the creation and policing of local rules to enable the sustainable use of natural resources, environmental education, the provision of alternatives to the unsustainable over-exploitation of natural resources, poverty alleviation, and the restoration of degraded ecosystems. While this approach is successfully conserving biodiversity in the short term and at local scales, over a longer time period these reserves will become increasingly threatened by a rapidly growing human population whose livelihood is dependent on natural resources that will become increasingly rare outside of protected natural areas. Extensive ecological restoration of landscapes surrounding reserves is a prerequisite in Madagascar for the long-term conservation of these protected areas and will thus be an essential part of a national effort to achieve Target 4 of the Global Strategy for Plant Conservation (GSPC). Here, we describe our current restoration program, analyze its strengths and weaknesses, and consider the threats and opportunities relating to restoration in Madagascar. This information is used to identify key attributes for a proposed up-scaled restoration initiative that can serve to develop more sophisticated methods, strengthen expertise through training, and demonstrate the power of ecological restoration for achieving long-term, sustainable conservation outcomes, as called for by the GSPC.

Key words: Ecological restoration, Global Strategy for Plant Conservation (GSPC), Madagascar.

With an area of 587,040 km^2, roughly similar to the area of California and Arizona combined, the island nation of Madagascar has a remarkably diverse flora that comprises nearly 12,000 species of vascular plants already described, belonging to over 900 genera and 239 families (Madagascar Catalogue, 2013a), plus as many as 2000 additional species that remain to be scientifically named (Phillipson et al., 2006). In comparison, the flora of North America includes around 20,000 native species in an area more than 40 times as large. Even more striking is the level of endemism in the Malagasy flora, which was recently estimated as 84% of the published vascular plant species, and an even more remarkable 35% of the genera (Callmander et al., 2011), figures that will increase as new taxa are described. However, this exceptional botanical wealth, which also includes five endemic families, is acutely threatened because of the immense ecological footprint of the rapidly growing, largely very poor, human population

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(2.65% demographic growth per year; Central Intelligence Agency, 2013).

Madagascar's rural people rely on subsistence agriculture for their livelihoods, yet nearly all increases in agriculture come at the expense of natural ecosystems. Between 1950 and 2005, the country lost 40% of its cover of forest, woodland, and thicket (Harper et al., 2007), and during this same period many plant species undoubtedly went extinct. Today, almost all of the island's exceptional flora is threatened by habitat loss, making Madagascar one of the five hottest of the world's 34 recognized biodiversity hotspots (Mittermeier et al., 2004). This situation underscores the urgent need for coordinated action, as called for by the Global Strategy for Plant Conservation (GSPC) as established in Montreal (Convention on Biological Diversity [CBD], 2011a, 2011b, 2011c, 2011d), with its far-reaching set of objectives and targets.

In this paper, we explore how the ecological restoration activities now being developed and conducted by the Missouri Botanical Garden's (MBG) conservation program in Madagascar could be expanded to contribute significantly to the implementation of the GSPC in Madagascar, and in particular to the GSPC Target 4, which calls for securing "at least 15% of each ecological region or vegetation type by 2020 through effective management and/or restoration" (CBD, 2011d).

Missouri Botanical Garden's Conservation Activities in Madagascar: A Platform for Developing Ecological Restoration

MBG supports active programs in more than a dozen countries. The largest of these programs is in Madagascar, where over the last 25 years the organization has developed a program with over 100 local staff members conducting a wide range of activities. Initially, the program focused on botanical exploration, taxonomic research, and in-country capacity building, with a special emphasis on training. Led by our local field botanists, MBG has conducted one of the world's most productive modern field inventory programs, and our staff has made a large contribution to understanding the Malagasy flora. The results of these efforts have been made available to the world through the publication of scores of taxonomic revisions, species descriptions, and the online publication of the Catalogue of the Vascular Plants of Madagascar (Madagascar Catalogue, 2013a). Starting in the late 1990s, local members of MBG's staff in Madagascar came to the realization that plant conservation efforts were far from adequate, which instilled a growing desire to play a more direct and active role in achieving realistic conservation goals.

As an initial step toward addressing the critical need for expanded plant conservation efforts, we used the large body of information on Madagascar's flora gathered over the last quarter century to identify priority areas for plant conservation, the goal of which was to ensure that no plant species are lost to extinction. In 2001, a total of 78 priority areas were identified (Andriambolonera & Raharamampionona, 2005; Raharimampionona et al., 2006). The following year, we launched a pilot project to conserve one of these priority areas, the Agnalazaha Forest, a rare fragment of littoral forest, one of Madagascar's most highly threatened ecosystems (Consiglio et al., 2006). We adopted a community-based approach that emphasized a combination of conservation of native ecosystems, environmental education, and sustainable local economic development. Based on the success achieved at Agnalazaha, we embarked on an expansion of our program over the last decade, and today we are working with local communities at 11 priority sites with a total area of nearly 60,000 ha. These sites are situated throughout the country and encompass a broad diversity of vegetation types, including dry forest and thicket (Anadabolava and Oranjia), littoral forests (Agnalazaha and Pointe à Larrée), low-elevation humid forest (Analavelona, Analalava, Makirovana-Tsihomanaomby, Vohibe, and Ankarabolava-Agnakatrika), sclerophyllous woodland and shrubland (Ibity Massif), and mid-elevation humid forest (Ankafobe). All but one of these 11 sites, the tiny Ankafobe Forest managed as a community reserve, have now been formally accorded temporary protection by the Malagasy government, the first of two stages in the process leading to the forest's permanent designation as an official, nationally recognized protected area.

The approach used by MBG to achieve long-term conservation at each site involves basing a full-time, well-trained, and highly motivated Malagasy Conservation Facilitator within the community, located close to the conservation site. This person engages local stakeholders in a negotiation process that leads to a mutually acceptable delimitation and management zonation for the conservation site, and the Facilitator works with the stakeholders to develop and implement a set of community rules (*dina*) that are grounded in traditional customs and specifically designed to support sustainable management of the area's natural resources. To mitigate the negative impact of restricting access to the natural resources contained in the area being conserved, MBG also works with a local Management Committee, which we

help to set up, to develop alternative resources for community members, and to identify and implement alternative income-generating methods for those persons whose livelihoods are most heavily affected. This basic approach is supported by ongoing research, monitoring, and information-sharing to enable informed decision-making by MBG, the community, and government agencies. In addition, sustainable economic development is actively promoted in these communities in order to reduce poverty and the resulting tendency to rely on the non-sustainable exploitation of natural resources. Examples of sustainable activities prompted at our sites include fish farming, organic gardening, nature tourism, and community-based plant nurseries.

The conservation program at each of the 11 sites where MBG is involved also includes a number of activities that contribute to ecological restoration, which may be defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed Society for Ecological Restoration [SER], 2004). Restoration activities include: (a) the control of particularly harmful, alien invasive plants such as the tea tree (*Melaleuca quinquenervia* (Cav.) S. T. Blake) and guava (*Psidium cattleyanum* Sabine); (b) the reduction of anthropogenic pressures, including burning and the unsustainable harvesting of trees, which constrain natural regeneration and reduce forest cover and integrity; and (c) the reforestation of degraded areas using native species with the aim to restore and expand the remaining forested area. The nature and scale of these actions at each of the 11 sites are summarized in Table 1.

Scaling-up Missouri Botanical Garden's Restoration Activities in Madagascar

While ecological restoration is making a positive contribution to conservation at each of MBG's 11 conservation sites, it is currently doing so within the limited context of a traditional fortress approach to conservation. In most cases, these sites constitute islands that are rich in biological diversity and natural capital but stand isolated in landscapes where these resources are much reduced and where most people are impoverished, relying on marginally productive agriculture for their livelihoods and desperately in need of access to resources. As long as this situation persists, external investment will be necessary to ensure that the natural fortress is not invaded. Although these reserves are successfully conserving biodiversity and providing ecological goods and services in the short term, it seems questionable whether this situation can be sustained over longer periods. A more stable future might, however, be envisaged if the Malagasy economy were to improve significantly and its population were to become less dependent on subsistence agriculture, although this does not currently seem likely. Alternatively, the long-term prospects of these reserves could also be improved significantly if the degraded landscapes surrounding them were to be restored, thus increasing their capacity to satisfy local requirements for natural resources. Thus, in a country such as Madagascar, the extensive use of ecological restoration may well be essential for achieving the sustainable, long-term conservation required to achieve Target 4 of the GSPC (CBD, 2011d).

While MBG's restoration activities in Madagascar are modest, our conservation program has several strengths on which more significant endeavors could be built. These include:

(1) The full-time presence of well-educated and highly motivated staff members at the conservation sites who have won the trust of the local community, have some experience of restoration interventions, and possess an understanding of the site-specific issues that impact whether restoration goals are reached;
(2) Well-developed, multi-faceted community-based conservation programs operating at each site that can facilitate restoration;
(3) A scientific ethos and intimate knowledge of the Malagasy flora that enable a rigorous and efficient science-based approach to restoration;
(4) An integrated network of conservation projects throughout the country that provides an opportunity for developing restoration protocols under diverse environmental and social conditions, and that facilitates the exchange of experience between restoration practitioners; and
(5) The presence at each site of largely intact natural vegetation that can provide both a reference ecosystem for setting restoration goals and key resources such as plant material and top-soil for implementing restoration activities.

The successful expansion of restoration activities at our sites will, however, require overcoming three major weaknesses. First, there is a paucity of public land near some of the 11 reserves that could be used for community-based restoration projects, which will require that we work closely with private landowners whose short-term land-use goals may be difficult to reconcile with the long-term goals of restoration. Second, there is a limited level of expertise and experience among our staff with regard to developing a robust restoration program and carrying out the full range of technical aspects needed for implementing

Table 1. Restoration activities at the 11 priority areas for plant conservation where the Missouri Botanical Garden is now facilitating conservation, restoration, and sustainable local economic development in Madagascar.

Site	Reforestation	Control of invasive alien species	Promotion of regeneration by reducing factors leading to ecosystem degradation
Agnalazaha	• Seedlings of native tree and shrub species propagated in village nurseries and planted in anthropogenic forest clearings (over six years, 30,000 seedlings produced and planted over 9 ha) • Research conducted to inform planting protocols (comparison of growth and mortality of seedlings with and without added compost in their planting holes)	• The local management committee supported for the establishment and implementation of local rules (*dina*) that encourage the use invasive species • *Melaleuca quinquenervia* felled in over 50 ha	• Risk of burning by wild fires reduced by creating firebreaks and by supporting fire-spotting teams during the dry season • New shifting cultivation stopped and exploitation of wood products (timber, fence posts, fuel) controlled by supporting the management committee in the development and application of local rules for forest use
Anadabolava			• New shifting cultivation stopped and exploitation of wood products controlled by supporting management committees in the development and application of local rules for forest use
Analalava	• Seedlings of native tree and shrub species propagated in village nurseries and planted in anthropogenic clearings within the forest (over six years, 31,000 seedlings produced and planted over 10 ha) • Research conducted to inform planting protocols (comparison of growth and mortality of seedlings with and without added compost in their planting holes) • Research conducted to define protocols for the vegetative propagation of native trees	• Research conducted to inform the development of a plan to control *Psidium cattleyanum* (comparison of costs and efficacy of various methods of controlling this invader)	• Risk of burning by wild fires reduced by encircling forest with a firebreak • Exploitation of wood products stopped by supporting a management committee in the development and application of local rules for forest use
Analavelona			• Risk of burning by wild fires reduced by creating firebreaks along the edge of parts of the forest that are most vulnerable to burning
Ankafobe	• Research conducted to inform the development of a restoration plan (classification and mapping of vegetation types and description of vegetation succession following forest felling and burning) • Anthropogenic grassland surrounding forest reforested using locally produced native tree seedlings (since 2005, 21,000 seedlings planted over 8 ha) • Research conducted to inform planting protocols (comparison of growth and mortality of seedlings in different size classes at time of planting) • Research conducted to inform planting protocols (comparison of growth rate of seedlings of four native pioneer species planted in anthropogenic grassland under two conditions: control versus added compost, mulch and shade)		• Risk of burning by wild fires reduced by encircling the forest with a double firebreak and supporting fire-spotting teams

Table 1. Continued.

Site	Reforestation	Control of invasive alien species	Promotion of regeneration by reducing factors leading to ecosystem degradation
Ankarabolava-Agnakatrika	• Research conducted to develop best protocols for the reforestation by the direct sowing of seeds of native trees in the sites where they will grow to maturity • Areas of former cultivation reforested within the forest using locally produced native tree seedlings (over one year, 3500 seedlings planted over 2 ha)		• Exploitation of wood products controlled by supporting several management committees in the development and application of local rules for forest use
Ibity Massif			• Research conducted to inform the development of a restoration plan for the site (relationship between fire frequency and vegetation types)
Makirovana-Tsihomanaomby	• Seedlings of useful native tree species propagated in village nurseries and planted in anthropogenic clearings within the forest (activity began in 2011)		• Exploitation of wood products and use of fire as an agricultural tool controlled by supporting several management committees in the development and application of local rules for forest use
Oranjia	• Seedlings of useful native tree species are propagated in village nurseries and planted in anthropogenic clearings within the forest (over two years, 3000 seedlings produced and planted over 4 ha)	• Research conducted to develop saleable, wooden handicrafts that could be made by local people using invasive alien species as an economic alternative to the exploitation of timber	• Exploitation of wood products controlled by supporting several management committees in the development and application of local rules for forest use
Pointe à Larrée	• Seedlings of native tree and shrub species propagated in village nurseries and planted in anthropogenic clearings within the forest (over three years, 23,000 seedlings produced and planted over 5 ha)	• *Psidium cattleyanum* controlled by uprooting and replanting the area it occupied with seedlings of native species	• Exploitation of wood products and use of fire as an agricultural tool controlled by supporting several management committees in the development and application of local rules for forest use
Vohibe	• Seedlings of native tree and shrub species propagated in village nurseries and young individuals planted in anthropogenic clearings within the forest (over six years, 50,000 seedlings produced and planted over 14 ha)		• New shifting cultivation stopped and exploitation of wood products controlled by supporting a management committee in the development and application of local rules for forest use

such plans. Third, to date, our restoration activities have been limited by funding constraints.

In addition to these strengths and weaknesses, several major external opportunities and threats will have to be taken into consideration as we develop restoration work at our sites. One important opportunity is the desperate need for new sources of income by rural populations in Madagascar, which strongly implies that if restoration projects are designed to maximize employment opportunities then they will likely receive strong support from local stakeholders and could contribute significantly to reducing poverty and the unsustainable use of natural resources. Another key opportunity is the presence in some parts of the country of large areas of degraded land that are currently perceived to have little value and thus could be made available for restoration projects without generating conflict with other land users. A significant threat, however, is presented by Madagascar's widespread poverty and the associated tendency to make land-use decisions that address short-term needs at the expense of compromising long-term options. Another threat is the current paucity of donors whose funding strategy is compatible with supporting the kind of long-term commitment needed for restoration projects to be successful. However, it is possible that the current REDD+ negotiations within the United Nations Framework Convention on Climate Change (UN-REDD Programme, 2009; Alexander et al., 2011), as well as discussions and ongoing projects under the CBD convention and the United Nations Convention to Combat Desertification (UNCCD, 2012), may lead to new funding opportunities for restoration in the coming decade.

The best approach to restoring the degraded ecosystems and fragmented landscapes in which the MBG's 11 conservation sites are situated will be to expand restoration activities to exploit these strengths and opportunities while addressing weaknesses and mitigating threats. These activities should seek to: (1) retain and strengthen local expertise; (2) encompass complimentary elements such as education and economic development; (3) employ a scientific approach that promotes regular evaluation and improvement throughout the life of the project; (4) promote the exchange of ideas and experience among restoration practitioners working at all 11 sites; (5) develop protocols that maximize the sustainable use of the natural resources available at each site; (6) seek incentives for private landowners to support restoration even if this sometimes requires adopting an approach that does not aim to restore entirely natural ecosystems; (7) increase MBG's capacity to design and implement ecological restoration; (8) exploit low-technology restoration methods that maximize rural employment opportunities; (9) focus restoration on highly degraded landscapes that have little current economic value; (10) collaborate with development organizations to reduce poverty in the vicinity of restoration projects; and (11) mobilize the full force of the botanical garden and conservation communities to secure support for expanding restoration projects and programs to ensure that restoration can make a significant contribution to biodiversity conservation and to achieving the targets set by the GSPC (CBD, 2011a, 2011b, 2011c, 2011d; cf. Hardwick et al., 2011).

The Importance of Model Restoration Projects to Inspire and Inform Expanded and More Effective Restoration Endeavors in Madagascar

MBG's current restoration activities in Madagascar are relatively simple and small scale, typical of those being implemented by other conservation organizations operating there and in many other developing countries. Two notable larger-scale restoration projects involving several hundred hectares are being undertaken in Madagascar at Fandriana-Marolambo (Roelens et al., 2010, unpub.) and within the Ankeniheny-Zahamena Corridor (Conservation International, 2011), but even they lack the sophistication of flagship restoration efforts elsewhere in the tropics, such as in Costa Rica (Janzen, 2002) and southeastern Brazil (Rodrigues et al., 2010). For the most part, restoration in Madagascar primarily aims to curtail human activities that lead to forest degradation and, thereby, promote natural regeneration while also planting native trees in areas where natural forest regeneration is thought to be blocked (Holloway, 2007). No projects effectively tap the full potential of large-scale, science-based ecological restoration for contributing to the conservation of Madagascar's biodiversity, increasing the country's natural capital, and promoting resiliency against climate change. Moreover, none of the current restoration projects can be regarded as a model of best practice for achieving effective ecological restoration. While Target 4 of the GSPC (CBD, 2011d) specifically calls for restoration, conservation decision-makers and technicians in Madagascar lack awareness of and exposure to successful restoration efforts, and they remain unconvinced of the importance of restoration. Model projects are, thus, urgently needed to increase the pace of progress toward achieving the GSPC Target 4. This will require additional investment and visibility, which MBG's conservation projects are in an excellent position to facilitate. Thus, while the long-

term conservation of MBG's 11 priority areas for plant conservation will require greater investment in restoration than at present, if this scale-up can be done in such a way as to create a series of model restoration projects, then our contribution to achieving the GSPC Target 4 in particular, and to promoting biodiversity conservation and improving human livelihoods in Madagascar in general, would be significant.

In conclusion, the experience we have gained from conserving 11 priority areas for plant conservation in Madagascar suggests that ecological restoration will be a prerequisite in most situations for successful long-term conservation and, therefore, must be an essential element in a national effort to achieve Target 4 of the GSPC (CBD, 2011d). However, despite the importance of ecological restoration, its current application in Madagascar is both small in scale and technically primitive. To help overcome these issues, MBG is now endeavoring to scale-up the restoration component of the conservation strategies at its 11 conservation sites, some or all of which could be used to test and implement more sophisticated methods, develop expertise through training, and provide operating models to demonstrate the value of ecological restoration for delivering the kinds of lasting conservation and development outcomes called for by the GSPC.

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